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LABORATORY STUDY ON THE OPTIMIZATION OF IPLT SUMUR BATU DEWATERING UNIT USING DIFFERENT COAGULANTS

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ABSTRACT

Aim: The aim of this study is to determine the most effective type and concentration of coagulant to reduce TDS, TSS, BOD and COD Sumur Batu Fecal Treatment Plant or *Instalasi Pengolahan Lumpur Tinja* (IPLT) Sumur Batu. **Methodology and Results:** Using the jar test method at a laboratory scale, the types of coagulants of PAC, Alum and FeSO₄ with varied concentration of 70 mg/L, 137.5 mg/L and 200 mg/L were used. Additionally, Polyacrylamide was also used in the study with concentration varied between 0.1 mg/L, 0.6 mg/L, and 1.1 mg/L adjusted to the concentration in the field. **Conclusion, significance and impact study:** The largest weighting occurred in the alum coagulant, which had 13.03 points. The polyacrylamide coagulant was the best economically when viewing the cost per year, but from a technical point of view, it is not adequately efficient because its ability to allow for the test parameters is still far from the removal ability of the alum coagulant.

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KEYWORDS

- Alum
- Coagulant
- Dewatering unit
- Fecal treatment plant
- IPLT
- Polyacrylamide

1. INTRODUCTION

Sumur Batu Fecal Treatment Plant, also known as Instalasi Pengolahan Lumpur Tinja (IPLT), is located in Bekasi, one of the most populated cities in Indonesia. It implements various mechanical systems that are more efficient and do not require extensive land area. Mechanical units in the Sumur Batu IPLT include the Sludge Acceptance Plant (SAP), chemical addition and dewatering units. Dewatering is performed using the 'flocculation-coagulation' process which is aimed to decrease the turbidity and concentration of the organic matter in wastewater. The process involves the transformation of colloidal particles in the water into clumps of floc, which is deposited and removed.

The coagulant concentration of polyacrylamide currently used in IPLT Sumur Batu is 0.6 mg/L. The high concentration lead to high cost of chemical usage and involves some operating difficulties, such as the slow formation of flocks. Therefore, pond aeration must be managed carefully and eventually increased in order to handle the load that enters the pond.

The effluent quality results in October 2017 showed Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) concentrations of 85.69 mg/L and 133.33 mg/L respectively. Both concentrations exceeded the water quality limits (under the Republic of Indonesia, Minister of Environment and Forestry Regulation, No. 68 (2016) which states a value of 30 mg/L for BOD and 100 mg/L for COD.

The type and dosage of the coagulant has an influence on the reduction of BOD and COD levels of the water. FeSO_4 at a dose of 3 g/L was effective in reducing the level of COD to 39.25% (Faris, 2012). $\text{Al}_2(\text{SO}_4)_3$ at a concentration of 16 g/L could reduce the COD and BOD levels up to 65% and 52% respectively (Rezagama, *et al.*, 2016). Polyaluminium Chloride (PAC) at a dose of 150 mg/L can reduce COD and BOD levels to 62.45% and 69% respectively (Jeplin, 2009). This research was conducted using three different types of coagulants, specifically FeSO_4 , Alum, and PAC. Each coagulant was dosed at three different concentrations of 75, 137.5, and 200 mg/L. A specific coagulant (Polyacrylamide) used by IPLT Sumur Batu was also examined in this study to find out its effectiveness compared to the other three coagulants. For Polyacrylamide, three different concentrations of 0.1, 0.6, and 1.1 mg/L were dosed. Furthermore, the effectiveness of the four coagulants was determined by studying how each affected the values of Total Dissolved Solids (TDS), Total Suspended Solids (TSS), COD, and BOD in IPLT Sumur Batu.

2. RESEARCH METHODOLOGY

This research was conducted in the laboratory using three different types and doses of coagulants. A polyacrylamide was also used in this experiment in order to compare the results from the three coagulants. Additionally, the Jar test procedure was performed for the coagulation and flocculation process Table 1 shows the matrix of the experiment while Figure 1 illustrates the stages.

Table 1 Matrix of the experiment

Coagulant type	Coagulant concentration		
	75 mg (B1)	137.5 mg (B2)	200 mg (B3)
Alum (A1)	A1,B1	A1,B2	A1,B3
FeSO ₄ (A2)	A2,B1	A2,B2	A2,B3
PAC (A3)	A3,B1	A3,B2	A3,B3

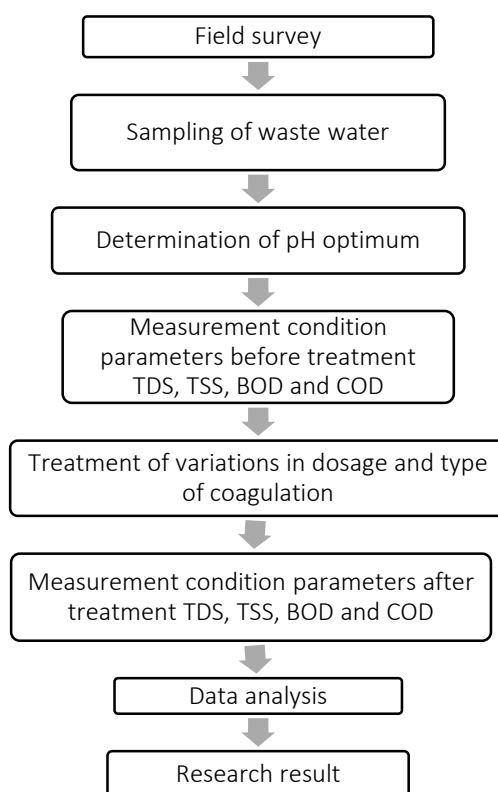


Figure 1 Research stages

2.1 Types and concentration of coagulants and Jar test

Three different coagulants were used in the experiment, namely FeSO_4 , Alum, and Poly Aluminum Chloride (PAC). These coagulants were selected due to their effectiveness and relatively cheap price for domestic wastewater treatment, especially in reducing TDS, TSS, BOD, and COD concentrations. In this experiment, the coagulant doses used were 75 mg, 137.5 mg, and 200 mg for 1 liter of wastewater. The dosage was determined based on the optimum value of the three coagulants. This study also used polyacrylamide coagulant, which is currently used in IPLT Sumur Batu. The aim was to compare the removal efficiency of the three coagulants previously described in reducing TDS, TSS, BOD, and COD concentrations with polyacrylamide.

In this experiment, the Jar test was operated at a fast stirring rate with a speed of 200 rpm for 1 (one) minute, while for the slow stirring, a speed of 20 rpm is performed at ± 20 (twenty) minutes. Subsequently, the settling period was approximately 10 - 15 minutes in order to let the formed flocs settle.

2.2 Data analysis

Results from this experiment were evaluated based on the reducing performance of each coagulant for different concentrations of TDS, TSS, BOD and COD.

3. RESULTS AND DISCUSSION

3.1 Total Dissolved Solid (TDS)

The results showed that there was a decrease in TDS values as the concentration of all coagulants increased (Figure 2). PAC was the most effective coagulant in reducing TDS concentrations. Additionally, Alum had a similar ability to PAC, at a concentration of 200 mg/L, both were able to reduce TDS concentrations by 348.9 mg/L (83.05%) and 368 mg/L (82.17%) respectively.

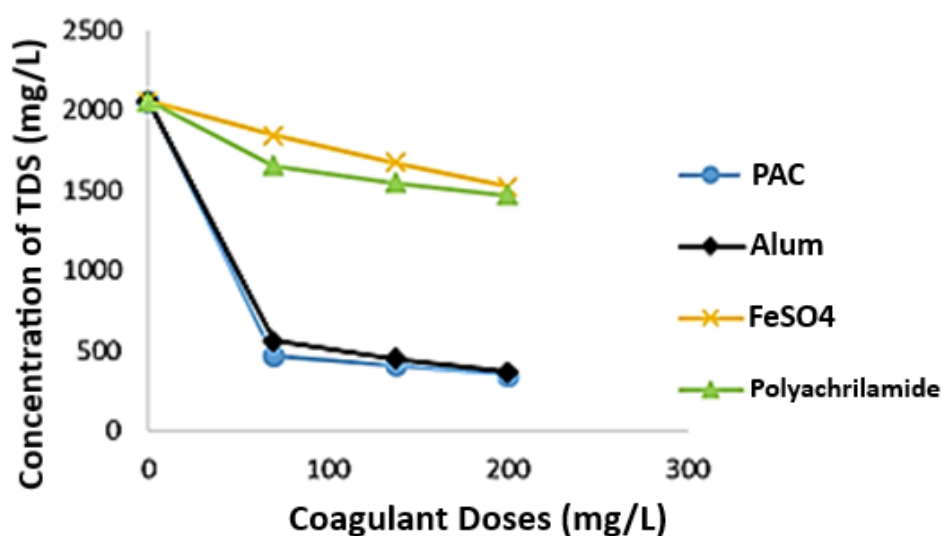


Figure 2 TDS reduction due to different coagulant types and concentrations

Decrease in TDS occurs due to a hydrolysis reaction in the PAC which releases Cl^- . Budiman (2008) stated that PAC is a special salt in the production of aluminum chloride and is able to provide stronger coagulation and flocculation than aluminum and iron salts, such as aluminum sulfate.

3.2 Total Suspended Solid (TSS)

Similar to TDS, TSS concentration had decreased with higher coagulant concentrations (Figure 3). PAC was the most effective coagulant in reducing the concentration of TSS. Again, Alum had a similar TSS removal ability to PAC. The highest removal degree was achieved by PAC, at a dose of 200 mg/L with a final concentration of 278.5 mg/L or 69.19% removal. The experiment showed more flocs formed with higher concentration of PAC added in the water.

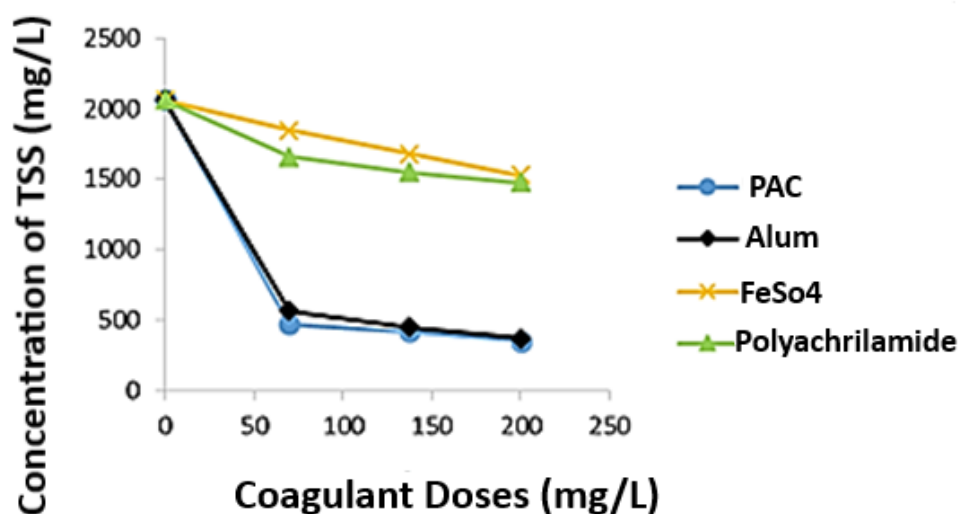


Figure 3 TSS reduction due to different coagulant types and concentrations

According to Budiman (2008), at a higher coagulant concentration, more cations are produced which react with colloidal particles (anions) in the sample water to form flocs. Subsequently, TSS concentrations will decrease. This is in accordance with the statement of Echanpin (2005) cited in Yuliati (2006), that PAC is an inorganic coagulant composed of macromolecular polymers which have a strong adsorption rate, high floc-formation levels despite small doses, fast sedimentation rates, and high efficiency as a water purification agent. According to Rossi (1993), cited in Fatoki (2002), floc removals in the form of liquid TSS depends on the type and amount of coagulant, colloidal suspension, pH, and chemical composition of the liquid.

3.3 Biochemical Oxygen Demand (BOD)

The BOD value decreased with increasing PAC, Alum, FeSO_4 and Polyacrylamide concentrations (Figure 4). In this study, Alum at a concentration of 200 mg/L is the most effective coagulant in decreasing the concentration of BOD. It had a removal efficiency of 60.16% with a final BOD concentration of 674.5 mg/L.

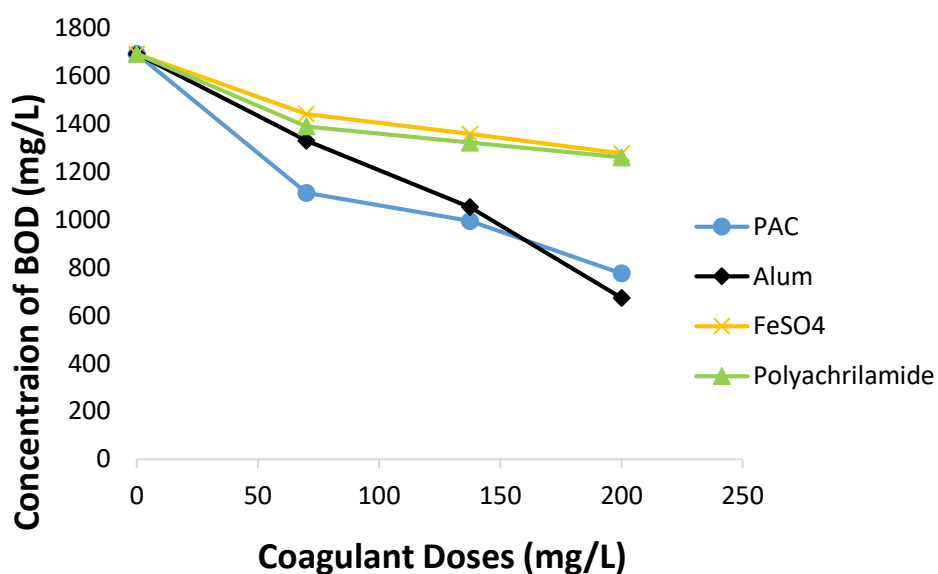


Figure 4 BOD reduction due to different coagulant types and concentrations

With the addition of suitable coagulant doses, the stability of the colloidal that had a negative charge in the system was disrupted as the Alum had a positive charge on the surface of the solution. According to Jeplin (2009), an increase in the electrolyte concentration can affect the potential energy which can eventually reduce the energy barrier in the colloidal system. In addition, the double layer force will be decreased, so the attractive blasing force, due to Van der Waals forces, will cause the particle charge to form a lump. Using this process, organic and inorganic pollutant levels can be decreased. Furthermore, low concentrations of pollutants will reduce the consumption of dissolved oxygen in oxidizing those impurities and reduce the BOD concentration.

3.4 Chemical Oxygen Demand (COD)

The COD value decreased with increasing PAC, Alum, FeSO₄ and Polyacrylamide concentrations (Figure 5). In this study, Alum is the most effective coagulant in decreasing COD compare to the others. The COD concentration was reduced from 2,758.67 to 1,010 mg/L or 59.76% COD removal.

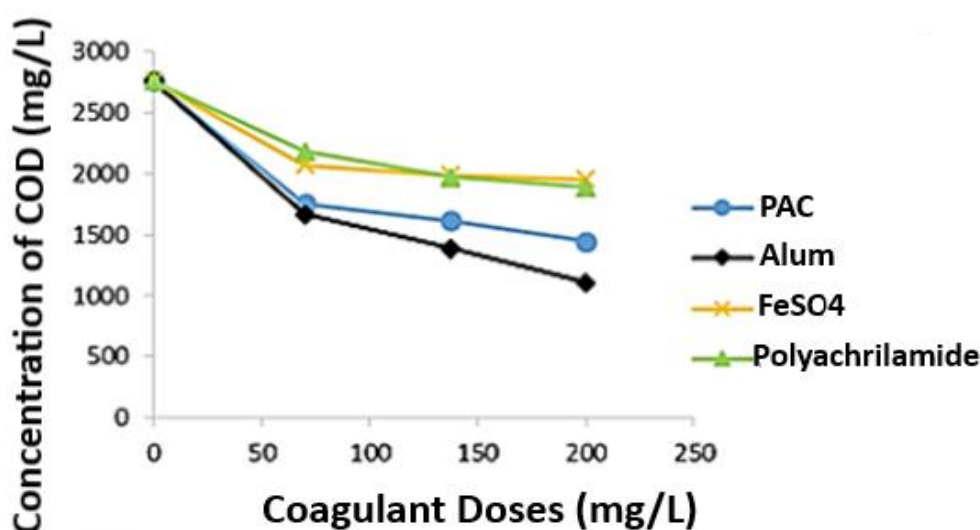


Figure 5 COD reduction due to different coagulant types and concentrations

Decrease in COD concentration is due to the ability of alum in eliminating suspended substances contained in water. Lower concentration of suspended substances will reduce the need for chemical oxygen (COD) process (Aziz, 2013).

3.5 ESTIMATED COST OF COAGULANTS

A cost estimation for each type of coagulant is required in order for the IPLT to determine the budget requirements. Additionally, cost estimation is also considered while selecting the most efficient type of coagulant. The operating time of the dewatering unit in is 10 (ten) hours per day and the discharge of wastewater is about 100 m³/day. Table 2 and 3 show the chemical price of each coagulant and the estimated annual operating costs.

Table 2 Price of chemical used

No	Coagulants type	Form	Rupiah/kg	Dose (mg/L)
1	PAC	Powder	4,500,-/kg	200
2	Alum	Powder	3,000,-/kg	200
3	FeSO ₄	Granular	78,000,-/kg	200
4	Polyachrilamide	Powder	73,000,-/kg	1.1

Table 3 Estimated operating costs per year

No.	Coagulants type	Uses dose (kg/day)	Cost a day (Rp)	Cost a year (Rp)
1	PAC	20	90,000	32,850,000
2	Alum	20	60,000	21,900,000
3	FeSO ₄	20	1,560,000	596,400,000
4	Polyachrilamide	0.11	8,030	2,930,950

3.6 RECOMMENDED TYPES AND COAGULANT DOSES

After obtaining the removal efficiency results for each coagulant, the appropriate coagulant type and dose to be used in IPLT Sumur Batu was selected. The results of this study show that Alum, at a concentration of 200 mg/L is the most effective coagulant that removed BOD and COD concentrations up to 60.16% and 59.76% respectively. The study confirms that Alum provided better pollutant removal and required lower costs than the coagulant currently used in IPLT Sumur Batu (Polyacrylamide).

In this study, polyacrylamide at a dose of 200 mg/L was also trialed to see its performance, the result showed that the floc formation was non-optimal at higher coagulant concentrations (Figure 6).



Figure 6 Floc formation with Polyacrylamide concentration of 200 mg/L

This phenomenon occurs because the coagulation process is more difficult as it does not affect the degree of hydration of the hydrophilic colloids. Furthermore, the dose needed for destabilizing colloids is approximately 10 - 20 times more than other coagulants (Said, 2017).

Table 4 Weighting the selection of the coagulant type

Weighting Factor Type of coagulant	PAC	Alum	FeSO ₄	Polyachrylamide
Technical Aspect:				
1. TDS Removal	4	4	2	2
2. TSS Removal	3	3	2	2
3. BOD Removal	3	3	1	2
4. COD Removal	2	3	2	2
Amount of weighting	12	13	7	8
Weight of operational cost a year	32,850,000/ 596,400,000 = 0.05	21,900,000/ 596,400,000 = 0.03	596,400,000/ 596,400,000 = 1	2,930,950/ 596,400,000 = 0.005
Amount of weighting	12.05	13.03	8	80.05

Note: Weighting from a technical aspect of view is based on pollutant removal ability

0 - 24.99% = 1

25% - 49.99% = 2

50% - 74.99% = 3

75% - 99.99% = 4

Based on Table 4, the largest weighting occurred in the Alum coagulant, which had 13.03 points because it was superior in technical terms and had a fairly economical value. The polyacrylamide coagulant was the best economically when viewing the cost per year, but from a technical point of view, it is not adequately efficient because its ability to allow for the test parameters is still far from the removal ability of the Alum coagulant.

4. CONCLUSION

Alum at a dose of 200 mg/L is recommended to be used in the dewatering unit of IPLT Sumur Batu due to its effectiveness compared to PAC, FeSO_4 and Polyacrylamide in decreasing BOD and COD concentrations. The effectiveness of Alum in decreasing the BOD value is 60.16% with the regression equation: $y = -4.9888x + 1,696$, $r = 0.9975$, while for the value of COD is 59.76% with the regression equation: $y = -7.8885x + 2535.4$, $r = 0.9422$. The effectiveness of TDS reduction for PAC coagulant is 3 times greater than polyacrylamide (28.50%); TSS for PAC coagulant is 1.99 times greater than polyacrylamide (34.73%); BOD for Alum coagulant is 2.35 times greater than polyacrylamide (25.52%) and COD for Alum coagulant is 1.89 times greater than polyacrylamide (31.52%). The Alum coagulant had the biggest weighting of 13.03 points, because it was superior in technical terms and had a fairly economical value.

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